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(71) Applicant (*for all designated States except US*): NEW TRANSDUCERS LIMITED [GB/GB]; Stonehill, Huntingdon, Cambridgeshire PE18 6ED (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): BANK, Graham [GB/GB]; 1 Boartree Way, Huntingdon, Cambridgeshire PE18 6GL (GB). AZIMA, Henry [CA/GB]; 3 Southacre Close, Chaucer Road, Cambridge CB2 2TT (GB). COLLOMS, Martin [GB/GB]; 22 Burgess Hill, London NW2 2DA (GB). HARRIS, Neil [GB/GB]; 9 Davey Crescent, Great Shelford, Cambridge CB2 5JF (GB).

(74) Agent: MAGUIRE BOSS; 5 Crown Street, St. Ives, Cambridgeshire PE17 4EB (GB).

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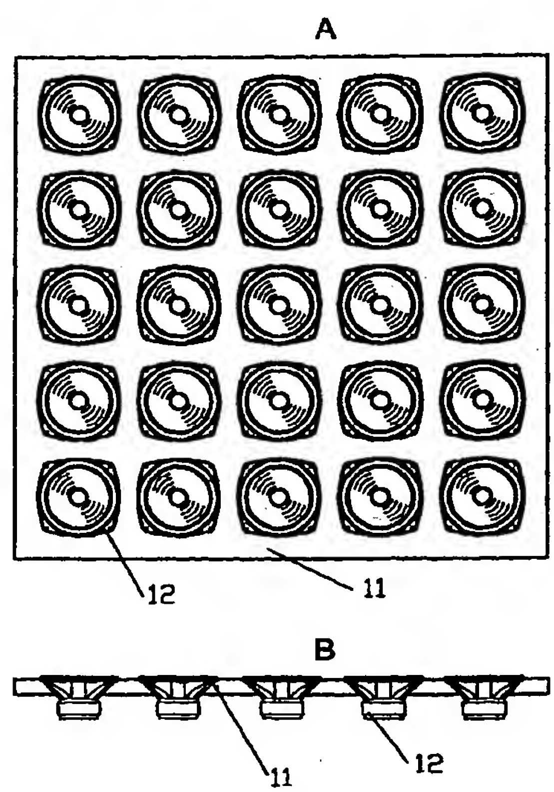
(54) Title: SOUND RADIATING DEVICES/SYSTEMS

(57) Abstract

Sound radiator has an areally distributed array of plural acoustic transducers having individual drive means. A large number of transducers can be used and can be of any type. Drive signals produce phase-different sound radiations from the transducers in distributions over the area of the array having desired diffuse or particularly voiced nature. Drive signal producing means involves phase-shifting higher acoustic frequency content, and is further operative for in-phase action of at least some of the transducers in sub-area(s) of the array for lower frequency content.



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TITLE: SOUND RADIATING DEVICES/SYSTEMS

TECHNICAL FIELD

This invention relates to acoustic devices, particularly to devices for producing and radiating sound typically in response to electric signals from appropriate electronic audio signal processing means; and specifically to novel forms of loudspeakers.

BACKGROUND

Conventional loudspeakers rely upon pistonic action to impart sound into ambient air using diaphragms driven basically reciprocally by electromagnetic means, typically cones intendedly operative on air in and forward thereof. Such conventional loudspeakers are variously characterised by box-like enclosures with often complex provision for rearward absorption of otherwise at least partially cancelling sound components that are opposite in phase to desired forwardly directed sound components; by directionality of desired forward sound in effective listening beam angles that are narrower the higher the frequency of reproduced sound concerned; and by fall-off of intensity of produced sound within such beam angles in a square-law manner with distance as though from a substantially point source close to which sound intensity can be very high for

powerful loudspeakers. Multiple unit cone type loudspeakers are well known with different sizes of cones operative for low, mid and high bands of audio frequencies, with consequent requirement for electronic cross-over networks for signals to such units.

Recently, we have been developing forms of acoustic devices including loudspeakers of radically new type, specifically as to acoustic action and resulting sound radiation, see PCT application no. GB96/02145). The acoustic action concerned for such loudspeakers relies on bending waves excited at particular prescribed positions in suitably constructed and configured panels for which resulting surface vibrations couple acoustically to air in a fundamentally non-pistonic manner. Resulting sound radiation can be effectively from the whole panel surface and over a very wide angular range producing highly diffused effects far, removed from above-mentioned intrinsic prior proximity loudness and directionality features, and over remarkably wide frequency ranges for individual panel units. Geometry and stiffness characteristics of such panels, along with careful location of exciter means, contribute to achieving such spread of resonant frequency modes of surface vibration effects as to promote the wide-ranging directionally diffuse sound radiation of great clarity and accuracy that contrasts strongly and beneficially with prior pistonic action loudspeakers and their often inconvenient limitations of good listening positions (perhaps particularly noted for stereophonic sound reproduction) inevitably consequent to narrowing beam-angle directionality, and often uncomfortably high proximity loudness inevitably consequent to point-source square-law fall-off effects. Moreover, prior preferences for different units dedicated to mid and high frequency bands and consequent cross-over networks can be rendered redundant, along with need for complex rearward absorption of sound components in box-like enclosures.

This invention arises from detailed consideration and reconsideration of acoustically advantageous features of successful distributed mode panel devices. Benefits of resulting diffuse radiated sound has been revealed to extend further to superior integration of radiated sound both relative to plural such panel loudspeakers in the same space (and wavelength related interference), and relative to reflection effects from boundaries of such space, e.g. walls and/or ceiling and/or floor (and standing wave interference); also to low perceived aural localisation and/or intrusiveness effects, thus better balance and/or mutual non-interference and smoothness of plural channels as for centre, front stereo and rear surround sound units in such as home theatre, or more generally in public address applications. First and most natural concern and focus for such consideration was towards whatever may be feasible in achieving yet better spread of resonant mode vibrations in bending wave sustaining panels and/or in excitation of such panels. However, and now very much underlying the purposes and aspects hereof, a quite different basis has been adopted by way of fundamental reappraisal, specifically as to basic contributions of above-mentioned diffuse nature of sound radiation, and how else usefully to achieve beneficially different sound radiation effects, whether or not of or effectively resembling that from distributed mode bending wave action loudspeakers. Results appearing hereafter in various aspects of the present invention are seen as representing yet more radically different approaches.

SUMMARY OF THE INVENTION

One such approach arises from noting characteristically effective phase coherence of sound from pistonic-action typically cone-type loudspeakers, and characteristically relative phase incoherence of sound from non-pistonic-action distributed mode panel loudspeakers relying on pending wave action.

According to one aspect of this invention, a sound radiator comprises an areally distributed array of plural acoustic transducer units having individually energisable drive or exciter means, and drive signals therefor are such as to result in sound radiations of differing respective phases, say directly related to imposed phasing of said drive signals, suited to such integration of individual unit outputs as to produce usefully diffuse and/or desiredly directional overall radiated sound from the area of said array rather or other than with prior narrowing beam angle with increasing frequency. Suitably disorderly or incoherent relation of said phases is envisaged for arrays of transducer units ranging from as low as 20 or less to as high as 750 or more.

It is believed to be useful at this point to mention known electrostatic loudspeakers representing, compared with cone-type loudspeakers, relatively large sound radiating areas that are effectively made up of individually pistonic-action sub-areas that operate with carefully orderly phase shifts so that such loudspeakers exhibit perceived coherence and point-source directionality of radiated sound, thus differ fundamentally from proposals hereof.

Returning to the above inventive aspect, desired phase incoherency of plural units producing diffuse perception of overall radiated sound that it proves upon directionality and proximity loudness of conventional loudspeakers is not essentially of similar nature to what happens in above-discussed distributed mode bending wave panels. Indeed, pursuit of such similar nature in terms of areal distribution of resonant frequency modes of such a panel might most naturally involve a matching unit distribution and operative frequency correlation of the transducer units. However, for panels as in above PCT application relying on bending wave action, areal distribution of resonant mode vibrations is complex and not evenly regular, and finding need for extensive pass-

filter provisions for full audio signals and/or differently tuned transducer units implied by in-principle assigning of frequencies to units individually and in groups is not attractive, at least compared with preferred implementations of this invention allowing use of regular arrays of transducer units and most if not all of frequency response capability of each of the units. Such preferred approach to implementation can further allow avoidance of inevitable limitations of bending wave action panels as to evenness of surface distribution of its active resonant modes, i.e. achievement of yet more even spread as well as independence from geometry and stiffness requirements for such panels.

At least for preferred diffuse radiated sound suitable distribution of different phases relative to individual transducer units of an overall array hereof exhibits disorder compared to generally coherent diaphragm type conventional loudspeakers, including above-discussed electrostatic type. In the same sense as available pseudo-random number generators and/or tables of random numbers aim to exclude high regularity and/or bunching, suitable phase distributions hereof can be considered as being randomised. As to phase differences themselves, individual and/or cumulative cancellation effects are readily avoided, e.g. readily achieved by such constraint as none being a whole number sub-multiple/divisor of 180°. It is, however, to be appreciated that, of self-evidently multitudinous possibilities, any particular distribution of particular different phases that is deemed to be satisfactory for any particular array of transducer units can be, and usually will be for simplicity, made or treated as fixed or prescribed for the implementation concerned. Also, the number of different phases may not need to be the same as the Number of transducer units, i.e. some could be the same so long as the number and distribution of different phases produces acceptable

perceived diffuse overall sound, a situation the more likely the more units there are in the array concerned.

Development work to date indicates that such implementations can achieve a range of audio frequency operation generally comparable with successful bending wave action panel loudspeakers, and superiority in terms of achievable evenness of radiated sound frequencies and perceived diffuse sound effects. Moreover, lower audio frequencies can also readily be handled, albeit somewhat differently. Thus, in the limit, lowest frequencies practical for size of array concerned can be dealt with effectively analogously to prior pistonic-action loudspeakers simply by corresponding drive signals being applied to all of the transducer units on an in-phase basis, i.e. substantially coherently. Resulting directionality is, of course, no more a problem than for prior large low frequency generally cone-type woofer loudspeakers well accepted as virtually non-directional. Such low frequency in-phase drive mode is applicable to less than all of the transducer units of an array hereof, i.e. only to the units of sub-area(s) of the array, say a medial usually central sub-area that could be shrunk progressively, typically step-wise, with frequency rising through the low range below what is well handled by above randomised different phase mode of operation.

It will be appreciated that manipulation of phasing of drive signals to individual acoustic transducer units of an array thereof represents a mechanism of great versatility and convenience in synthesising desired radiated sound effects, and constitutes another aspect of this invention not necessarily limited to combining substantially coherent and incoherent modes of operation for different bands of audio frequencies, nor to the transducer units concerned being adjacent in sub-areas or patches of the full array area, i.e. possibly in other patterns found beneficial, say in rings or at corners.

It has further been established that manipulation of

amplitudes of drive signals to individual acoustic transducer units of an array thereof can have beneficial effects in terms of perceived overall sound radiated by the array, and areal distribution of different amplitudes of drive signal for such transducer units constitutes another aspect of this invention, whether or not accompanying above phase distribution as is preferred herein.

Reverting to operation of acoustic transducer units of an array thereof in an orderly phased manner, it is further feasible to simulate alternative(s) to above wholly or partially in-phase mode, specifically for any desired direction(s) of stretched string vibration, or stretched membrane vibration, for which multiple-tap delay line may be used to feed individual units, and/or bending wave vibration for which single second-order recursive all-pass filter may be used for each unit, feasibly with different cross-over frequencies for mode transition(s) at each unit. Such other mode(s) of operation may, of course, be additionally available, and availability of two or more modes of substantially orderly and/or disorderly phased and/or amplitude operation constitutes a further aspect of this invention.

Regarding physical construction, it is preferred for array(s) of individual transducer units hereof to have common sheet- or panel-like carrier means, whether of flexible or stiff nature and presenting surface(s) that need not be flat planar, i.e. could be curved in one or more directions and/or faceted. As well as facilitating fabrication of an array (as such) of small transducer units, preferred carrier means can further assist desired application of drive signals individually to such transducer units, conveniently as a substrate for related conductor patterns, say after the well-established manner of printed circuit boards. Indeed, such carrier means may also usefully serve in mounting of local drive signal circuitry such as of modular semiconductor integrated

circuit type. Further impact of such carrier means can, of course, be in promoting approach to effective achievement of an idealised overall sound radiating surface exhibiting substantially random vibration with desired low or minimal in-phase content in resulting sound output. This can be to such extent perceptually that radiation of sound will be with such phase incoherence as to have much lower (or wider) directionality regardless of frequency than for conventional pistonic action loudspeakers, a feature that leads to much more even distribution of sound power with frequency.

Useful benefits thus arise without seeking to match what actually happens in successful panel loudspeakers, including specifically using presently practical small sizes of desirably high efficiency cone-type pistonic-action diaphragm units. Suitable units can be of the order of only about ten millimetres in diameter and have as low as 5% - 10% moving mass (compared with customary cone-loudspeaker design practice), say about 50 milligrams per transducer unit, which have not hitherto been considered as viable for much beyond low quality sound reproduction, but actually have significant advantage for the purposes hereof by reason of already being so small as to have sound radiation patterns that are of more spherical multi-directional than axially directed nature.

Development of yet smaller units, whether of electro-dynamic including moving coil electromagnetic type(s) or of other types such as crystal or polymer piezoelectric or electret or whatever, including application of so-called micro- or nano-engineering machine techniques, is to be expected by natural progress of technology once relevant interest is provoked, whether or not hereby, and can be expected dramatically to extend beneficial application of the invention. Indeed, it is already apparent, and intrinsic hereto, that the smaller the units and the larger their number the greater can be the benefits hereof, particularly as parallel development of low-cost

integrated circuit drive signal means and signal processing means of high capacity and performance, including of digital data processing or computer type, is believed to represent little if anything more than straight-line evolution of semiconductor and computer technology.

Particular transducer units will be chosen or designed according to power handling, bandwidth and maximum pressure level characteristics and desiderata. For arrays hereof with lower numbers of transducer units, line drive is feasible using semiconductor integrated circuits for modular amplifier sets, say of CMOS type, and digital-to-analogue converters for digitally processed signals. Resistive summation from a low bit-capacity decoder is feasible. For arrays with larger numbers of transducer units, say above about 750 units, natural recourse is envisaged to other technology such as involved for direct digitally driven loudspeakers relying at least partially on integration properties of the human ear.

Use of digital signal processing as available and evolving with ever higher computing power can readily handle synthesis of sound radiation of any desired nature, including imposing desired directionality rather than the diffuse nature of first above concern herein. Resulting signal coding can readily incorporate audio content along with any and all of phase and/or amplitude functions desired for the transducer units of arrays hereof, and undesirable transitions, such as between all-zero and all-one sequences can be avoided.

Reverting further to transducer units, local driving provisions therefor and the carrier means of the array, local drivers can be row-and-column addressable and time and line multiplex coded for response to digitally processed signals, and the carrier means can have printed circuit paths for addressing etc, if necessary or desired in plural layers of metallisation. Moreover, the transducer units may also, be formed in or on the carrier means

with benefit from technology developed and evolving for semiconductor integrated circuits, particularly highly sophisticated lithography techniques; and as first indicted above the units may be of electrostatic, thin or thick film piezoelectric type(s), or reliant on micro-engineered machine technology for the making of very small devices with moving parts, thus applicable to moving coil or lever assisted electrodynamic units typically as using high efficiency neodymium permanent magnets and operated in external polarising field(s). Suitable piezoelectric materials include crystalline types, e.g. barium titanate, or high polymer electrets; and multi-layer transducer units are readily fabricated together using layer printing commonplace in semiconductor processing. Preferred sizes of transducer units are below 20 millimetres each. Aforesaid sophisticated lithographic techniques may also be applied to carrier means such as of flexible films that have acoustic transducing action in themselves and have multi cell drive positions suitably conductively connected in a matrix array.

BRIEF DESCRIPTION OF DRAWINGS

Specific implementation(s) embodying the above aspects of this invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:-

Figures 1A and 1B are outline front plan and edge-on views of first matrix-like rectangular array of panel-mounted moving-coil type transducer units;

Figures 2A and 2B are similar views of second generally circular array of panel-mounted moving-coil type transducers;

Figures 3A and 3B are similar views of a larger matrix-like rectangular array of panel-mounted moving-coil type transducer units;

Figures 4A and 4B are similar views of a 10 x 10 array of sheet- or membrane-mounted piezoelectric transducer units;

Figures 5A and 5B similarly show transducer unit sites formed by selective metallisations of a piezoelectric sheet or membrane;

Figures 6A - D show electro-mechanical film type embodiment;

Figure 7 is an outline block diagram of a multichannel audio system with implementation of this invention; Figure 8 is an outline block circuit diagram for out-of-phase and low frequency in-phase operation of an array loudspeaker;

Figure 9 likewise shows further low frequency options; and

Figure 10 is a schematic circuit diagram for implementation by digital signal processing in a program controlled computer system.

DESCRIPTION OF ILLUSTRATED EMBODIMENTS

In Figures 1, 2 and 3, conveniently stiff or rigid carrier panels 11, 21 and 31 of structure other than preferred for implementing above-discussed bending-wave-action distributed resonant mode loudspeakers (of our PCT application no. GB96/02145) are shown with moving-coil transducers 12, 22 and 32 mounted with their cones extending through arrays of apertures in a manner believed to be self-explanatory. The transducer units 12 and 32 are in matrix-like 5 X 5 and 20 X 20 rectangular arrays, and the transducer units 22 are in circular array having 6X and 12X inner or medial and outer rings about a central said unit. If desired or preferred, generally rectangular arrays could have more or less rows and/or columns of equal or unequal numbers of transducer units, perhaps involving binary powers, and such units might be in adjacently staggered relation from row to row and/or column to column, say by half pitch and partially intercalated to increase the density of unit population of the panel; generally circular arrays could have different numbers of transducer units in first and second rings and/or more rings of transducer units with any practical

relation of ring populations and/or partial intercalation of progressively outward transducer units; and other arrays are feasible, for example of simple or staggered successively triangular or polygonal nature, or of compound type involving combinations of such distribution shapes, or even of irregular nature that might satisfy even or varying unit density desiderata.

Figures 4 and 5 each show carrier sheets or membranes 41 and 51 with matrix-like 10 X 10 rectangular arrays of transducer units 42 and 52 in rows *a* - *j* and columns *1* - *10* and with unit designations *a1* - *j10*. The transducer units 42 can be of individual piezoelectric type affixed to the sheet or membrane 41, and the transducer units 52 can also be of piezoelectric type but in this case formed and defined by registering metallisations 52A and 52B on opposite surfaces of intrinsically piezoelectric material of the membrane or sheet 51, say of high polymer type. Similar distributional variations are feasible to those outlined above. However, row-and-column addressing is envisaged conforming to the labelling of the units, i.e. with a corresponding one of each of sets of row-following and column-following conductors (not shown) energised, see further below regarding digital signal processing.

Figures 6A - D show implementation using dielectric film 63 as a moving acoustic diaphragm between front and back porous stator plates 64F, B. Such electromechanical film devices operative acoustically are well known in the art, including using inherently conductive or conductively coated stator plates and multilayer films having oppositely charged layers selectively metallised with, or to each side of a layer carrying, conductive electrode provisions. Cavities formed as registering depressions 65F, B in facing surfaces of the stator plates permit acoustically active localised deflections of the film 63 (rather than alternative of magneto-structure thickness variation to date usually less effective for loudspeakers). The depressions 65F, B are shown rounded or

domed with dashed references in Figure 6C, but otherwise, specifically peaked pyramidal in Figures 6A, B.

Localised plate-like electrode formations 62F, B are shown on opposite sides of common electret sheet 63 local to each cavity with individual conductive paths 66F, B for individual energisation for the purposes hereof.

Also omitted from Figures 1 - 6 are envisaged drive amplifiers (see labelled A in later Figures) individual to each transducer unit T, and which may be of semiconductor integrated type, whether conveniently mounted on the carriers (11, 21, 31, 41, 51, 63), say at undersides, or to an underlying printed circuit board, say with connector pins engaged with plated holes connected to the amplifiers them-selves supplied via conductive tracks in one or more layers of metallisation as appropriate.

Figure 7 shows audio system implementation in a multi-channel environment comprising electronic source 100 serving to supply electric audio signals to channel outputs 101 - 105 as for such as home movie or other stereophonic surround-sound applications involving the now familiar left and right plus centre forward speakers and pair of rearward loudspeakers, in this case with all five loudspeakers 111 -115 each indicated as being of array type and embodying this invention, see particularly and typically array loudspeaker 113, by way of plural transducer units T1 - Tn as above and individually associated drive amplifiers A1 - An. Audio signal supply lines S1 - Sn for the amplifiers A1 - An of each of the array loudspeakers 111 - 115 are shown supplied from phase and/or amplitude setting and routing means 121 - 125. It will be appreciated that the array loudspeakers 111 - 115 need not be all of the same type, nor all have the same number of transducer units T1 - Tn, i.e. "n" may be different for each, though left and right forward stereo loudspeakers will normally be the same, as will the usual rearward loudspeakers; and that, in any applications of this invention where loudspeakers would receive

essentially the same signals, array loudspeakers embodying this invention would be supplied from common phase and/or amplitude adjustment means.

Figure 8 shows a simple implementation of suitable phase setting by way of branch 131 shown from channel audio signal line 103 delay line 132 having multiple taps D1 - Dn to produce phase changes between 0° and 360° that have the inter-relationships as above indicated for desired resulting diffuse sound from transducer units T1 - Tn when appropriately applied thereto, here shown via "randomising" routing circuitry 133 serving to connect the differently phased audio signals on lines D1 - Dn in a suitably disorderly manner to the transducer unit drive lines S1 -Sn. Whilst there is implication that each and every one of the transducer units T1 - Tn has a unique phase applied thereto, that may not need to be the case, i.e. the number of delay line taps, this lines D1 - Dn could be less than the number of transducer units, thus drive lines S1 - Sn, even some submultiple. If some of the transducer units do receive the same phase of audio signal, it is usually preferred that are not all adjacent, indeed distributed beneficially (or at least non-damagingly) to achieving acceptably diffuse sound results, though they might well be arranged symmetrically in the array. For submultiple relationship, the number involved is preferably sufficient if applied to a sub-area or patch of the array to achieve acceptably diffuse sound results in its own right, and arrangement in a total array might well have symmetry of such sub-areas in appropriately adjacent relationships and/or transforms of the same patterns and/or different patterns each effective as aforesaid and further in actual combination.

Full or partial phase "randomising" can be represented by the following :-

$$\phi(n, m, \omega) = \text{random number on } [0, 2\pi)$$

where n and m represent the transducer unit populations of

rows and columns whether of a full matrix-like rectangular array or a said sub-area thereof.

The channel audio signal line 103 is also shown going to a low pass filter 135 for producing such low frequency outputs as benefit from being applied to the whole array with an in-phase relationship simulating pistonic loudspeaker effects, as discussed above, see filter output 136 connected directly to all of transducer drive lines S1 - Sn. It will be appreciated that, also as discussed above, there may be benefit from application of low frequency signals on line 136 to less than all of the transducer units T1 - Tn of the array loudspeaker concerned, say conveniently to a medial usually preferably central, sub-area resembling a window. Figure 8 includes such provision as will now be described.

Figure 9 differs from Figure 8 firstly in illustrating action for transducer units T1 - Tm of part 113a only of an array loudspeaker hereof, specifically a row or column of a rectangular matrix-like overall array, with corresponding indication of transducer unit drive lines S1 - Sm and part 132a only of delay line provisions with corresponding tap output lines D1 - Dm. It may be convenient to consider completion of provisions for the whole array as further sub-arrays of transducer units above and/or below or in front and/or behind those (tl - Tm) in row or column part 113a, likewise with delay line part 132a (say as parts serially connected end-to-end) and with "randomising" routing means 133a.

Turning to low frequency provisions without phase "randomising", output 136 from low pass filter 135 is shown branched at 137 for connection to less than all of output lines R1 - Rm of the "randomising" routing part 133, specifically to a medial number at RX. If similarly applied to outputs of each of all other parts of the "randomising" routing means, the result would be for only a centralised band of the transducer units to receive in-phase low frequency signals on branch line 137, but such

band could have its ends reduced to give an all-round "window" effect if outputs of outer ones of parts of the routing means do not have connections to the branch line 137. Line 136 is further shown going to another low pass filter 138 for providing lowest frequency signals on line 139 connected to all others of the outputs from the routing means, see at RY1 and RY2 of part 133a, thus increasing the number of the transducer units driven by such lowest frequencies to the full loudspeaker array. If desired, there could be more filter stages and more and/or other steps in increasing the numbers of array transducer units driven in-phase from a minimum band or window to a maximum that could be less than the full array. Additionally or alternatively, there could be pass band filters and/or in-phase energisation of sub-areal patches of the array, say for frequencies above low or at least lowest filtering as just described, basically according to pattern(s) of connections of their outputs to the outputs of the routing means.

Figure 9 further shows another multiple-tap delay line or delay line part 141a fed over branch 142 from the low pass filter output 136 and having its outputs connected in order to the outputs of the routing means, see at M1 - Mm and R1 - Rm for part 133a, usefully with such phase differences and driving of the array transducer units as to simulate sound output as though from a stretched string or membrane. It will be appreciated that other further delay line parts and/or other sets of tap outputs could service connections to others of routing means outputs in whatever manner required or desired. Also, Figure 9 shows another branch 145 taken from audio channel signal line 103 to each of plural filters 146, one per transducer unit of area(s) up to all of the array, see filter outputs labelled F1 - Fm to corresponding routing means outputs R1 - Rm; these filters 146 preferably being of second order recursive all-pass type up to a predetermined frequency which may serve as a cross-over

frequency to only-diffuse transducer unit operation and be different for each or sets thereof, and serving to produce desired resulting sound effects, say to simulate travelling wave vibration as follows :-

$$\phi(n,m,\omega) = k|r| = \frac{\omega}{c(\omega)}\sqrt{(n-N)^2 + (m-M)^2}$$

Figure 9 further shows additional amplitude varying means 151 for signals on outputs from the routing means that will have no effect unless enabled into operation for which several modes are envisaged, see outputs 152 from node specification block 153 shown with specifications for outer or frame regions (153F) or corners (153C) or patches (153P) or tapering (153T) or other (153X) effects, along with level setting (153S), as readily achievable by an array of variable amplifiers and selective control connections thereto at least somewhat after the manner (but as desired and appropriate) of connections above indicated for sets of lines to the routing outputs. One example of useful other (153X) effect is in accordance with Fourier transform theory and in conjunction with related phasing to produce arbitrary far-field pressure response(s), for which, of course, other delay line and/or tappings may be required and provided. A general Fourier transform equation for level p and phase o is as follows :-

$$p(\omega,\theta) = \sum_n \sum_m A(n,m,\omega)\exp(j\phi(n,m,\omega))\exp(jkr(n,m))$$

Manipulations of phasing and amplitude of signals are matters readily handled by program controlled digital data processing of digital versions of signals, with great flexibility and certainty, including as to implementing equations and combination and further manipulation of composite results. Accordingly, particular benefit is seen

in producing above and further useful features and effects digitally rather than in the analogue manner of Figures 8 and 9. Thus, turning to Figure 10, a digital data processor 161 that will include its own immediate working memory/ storage for data and in-use program material is shown in outline association via parallel bus provisions 162A, B with high-capacity memory 163 holding data and programs relating to useful modes of phase manipulation including for randomising (163R), simulations of stretched membrane (163M) and travelling wave (163T), and controlled according to Fourier transform (163F); and of amplitude manipulation including window and/or patch (163W/P), frame and/or corner (163F/C) and Fourier transform (163F) modes; and for general and specific control purposes (163C) including by which said modes are selected and implemented automatically according to installed software, see schematic dashed extension of the data processor block 161 and bi-directionally arrowed dashed lines therethrough to and from referenced content blocks of the memory 163. External specification of the various modes 163F, 163R, 163T, 163F, 163W/P, 163F/C are shown by way of correspondingly lettered etc inputs to input/output provisions 165 and schematic dashed extensions through the data processor block 161. Data input and output buses are indicated at 166A, B between the input/output provisions 165 and the data processor 161, though (and as for the buses 162A, B) a single bus might well be used on a multiplexed basis by preferred very fast data processors.

Indication is also given of alternative input for analogue and digital audio signals, see sources and channels 100A, 101A - 105A and 100D, 101D - 105D, respectively, going to multiplexors 171A, D. Analogue multiplexor output 172 is shown branched at 173 for low pass filtering at 174 onto line 175 with both of lines 172 and 175 going to analogue-to-digital (ADC) conversion stage 176 feeding parallel input buses 177 and 178. Parallel digital channel outputs 101D - 10SD are assumed

with parallel output effectively onto the input bus 177, though they could be serial and converted to parallel at output of multiplexing. In practice, whether digital audio signals are serial or parallel is largely a matter of choice if the data processor 161 is fast enough to service the array loudspeakers hereof for each channel from serial signals. Moreover, illustrated multiplexing and ADC can be expected to be done within the input/output provisions 165, probably under control of a microprocessor subsidiary to the data processor 161, i.e. then with only a low pass filter (or more as above) connected up externally (and possibly even to use for the digital audio if conversion to analogue form within block 165 is preferred to equivalent digital signal manipulation), even omitted if equivalent digital signal manipulation is preferred, i.e. after such conversion that is required in any event.

Turning to servicing of each of array loudspeakers hereof, such as again part referenced 113a for acoustic transducer units T1 - Tm with associated local amplifiers A1 - Am, individual digital-to-analogue converters DAC1 - DACm are further shown feeding said amplifiers A1 - Am. Whilst parallel feed bus branches B1 - Bm are shown from digital system output 181 to each of digital-to-analogue converters DAC1 - DACm, serial supply can be made in fast enough digital data processing systems, say with shift plus latching registers for substantially continuous analogue drive signals for the acoustic transducer units from the latching register content conversion between shift register loadings. At least then, and given presence of local final drive signal conditioning amplifiers (A1 - Am), it may be preferred and practical to incorporate all relevant DAC and register provision in or associated with the system input/output block 165, i.e. have single line analogue signal outputs to the local transducer unit amplifiers.

It will be noted that the amplifiers A1 - Am of Figure 10 are shown as being of gated (G) type,

specifically of two-input AND-action type to facilitate individual row-and-column addressing to specify transducer units desired to be active at any one time, or even on a multiplexed basis for different mode signals if resulting duty cycles are good enough for satisfactory sound production. Sets of row (R) and column (C) addressing lines are shown from the input/ output provision 165, including those specific to gating of the illustrated amplifiers A1 and Am. In practice, economy of wiring would benefit from the data processing system and its input/output provision producing serial binary words specifying, say digit-by-digit, and periodically changing the rows and columns to be addressed by receiving circuitry at the carrier of the array loudspeaker.

CLAIMS

1. Sound radiator comprising an areally distributed array of plural acoustic transducers having individually energisable drive means, and means for providing drive signals resulting in phase-different sound radiations from the acoustic transducers.

2. Sound radiator according to claim 1, wherein the drive signal providing means is operative to apply phase-different said drive signals to said drive means with a distribution of phasing over the area of the array that aids achieving diffuse overall sound radiation.

3. Sound radiator according to claim 1 or claim 2, wherein the drive signal providing means is operative to apply phase-different said drive signals to said drive means with a distribution of phasing that is disorderly over the area of the array to achieve incoherent overall sound radiation.

4. Sound radiator according to claim 1, wherein the drive signal providing means is operative to apply phase-different said drive signals to said drive means with a distribution of phasing that emulates a desired voicing of overall sound radiation.

5. Sound radiator according to any one of claims 1 to 4, wherein the drive signal providing means is operative to impose different phasing to substantially the same frequency content of an input signal.

6. Sound radiator according to any preceding claim, wherein different phases concerned are randomised.

7. Sound radiator according to any preceding claim, wherein differences of phase concerned are other than whole number submultiples or divisors of 180°.

8. Sound radiator according to any preceding claim, wherein phase differences concerned have up to one-to-one unique correspondence with the transducers, respectively.

9. Sound radiator according to any preceding claim,

wherein the drive signal providing means is operative as aforesaid for acoustic frequency content above lower frequencies for which the drive signal providing means is further operative to cause in-phase sound radiations from at least some of the acoustic transducers.

10. Sound radiator according to claim 9, wherein said some acoustic transducers are of sub-area(s) of the array.

11. Sound radiator according to claim 9 or claim 10, wherein said some acoustic transducers are substantially central of the array.

12. Sound radiator according to claim 9, 10 or 11, wherein said at least some acoustic transducers are greater in number and corresponding said sub-area(s) of the array greater in size the lower the acoustic frequencies concerned.

13. Sound radiator according to any one of claims 9 to 12, wherein the drive signal providing means has associated filter means for said lower frequency acoustic content of an input signal or bands thereof.

14. Sound radiator according to any preceding claim, wherein said array has at least 20 said acoustic transducers.

15. Sound radiator according to any preceding claim, wherein said array has up to 750 or more said acoustic transducers.

16. Sound radiator according to any preceding claim, wherein said acoustic transducers are of pistonic-action type.

17. Sound radiator according to any preceding claim, wherein said acoustic transducers are of cone-drive type.

18. Sound radiator according to any one of claims 1 to 15, wherein said acoustic transducers are of electrostatic type.

19. Sound radiator according to any one of claims 1 to 15, wherein said acoustic transducers are of piezoelectric type.

20. Sound radiator according to any one of claims 1 to

15, wherein said acoustic transducers are of electro-mechanical film type.

21. Sound radiator according to any preceding claim, wherein said acoustic transducers have associated carrier means common to all or groups thereof.

FIG. 1A

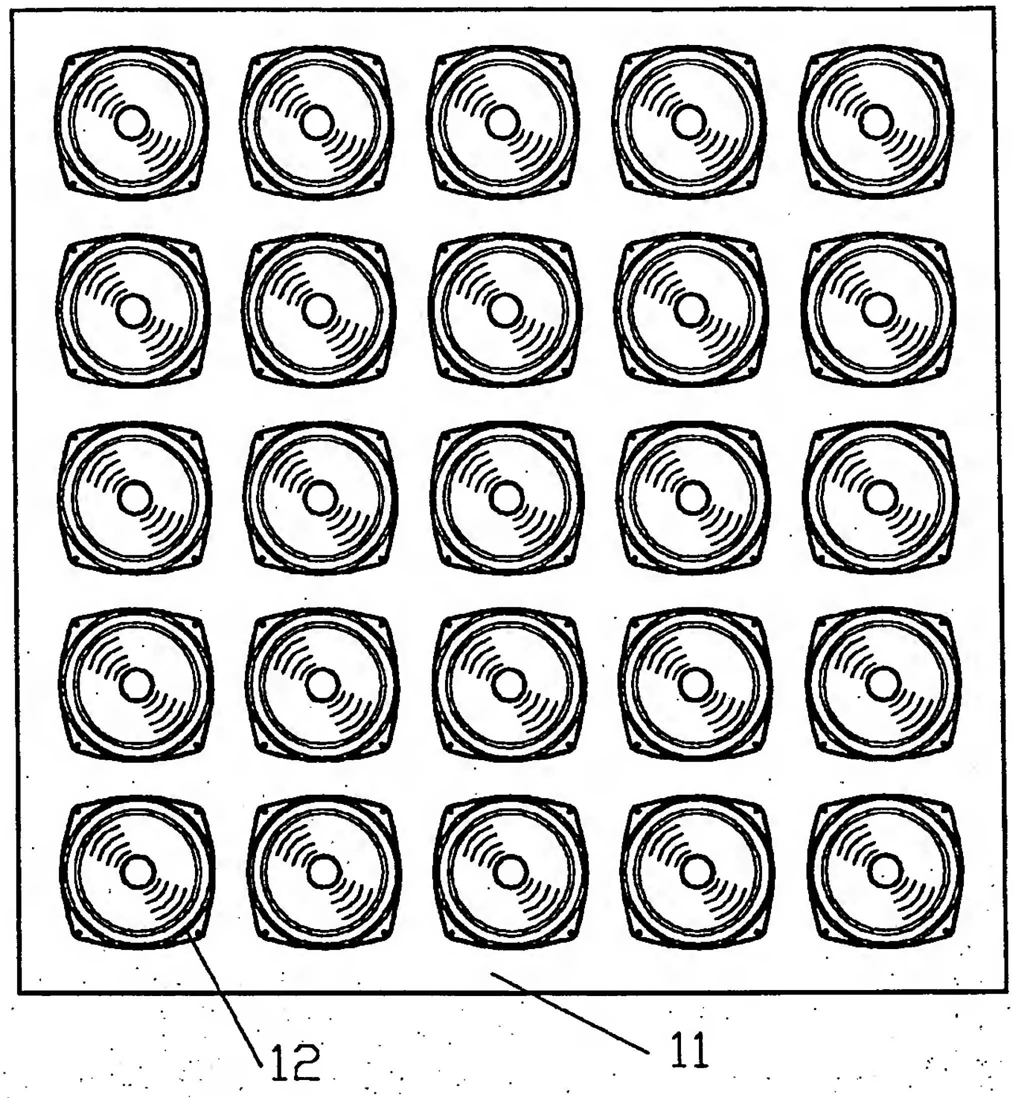


FIG. 1B

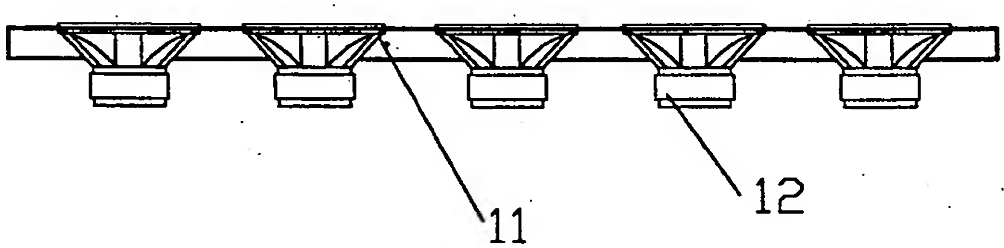


FIG. 2A

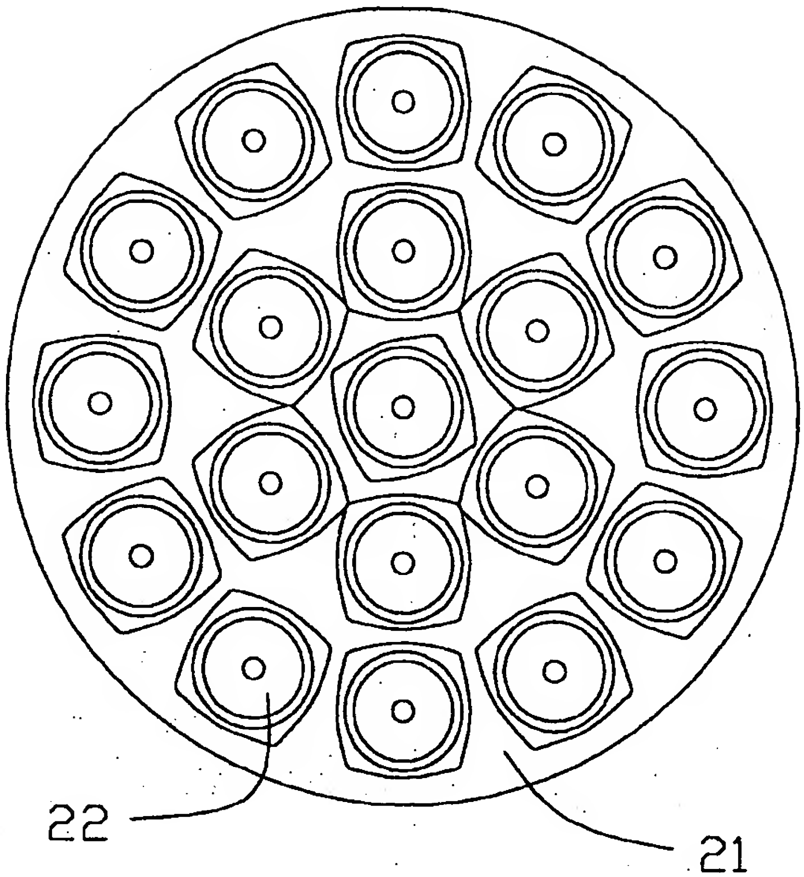


FIG. 2B

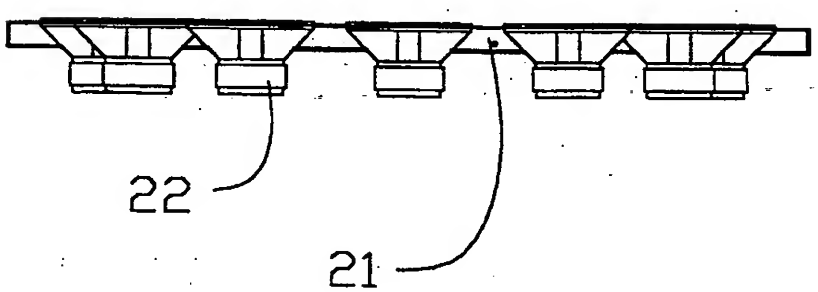


FIG. 3A

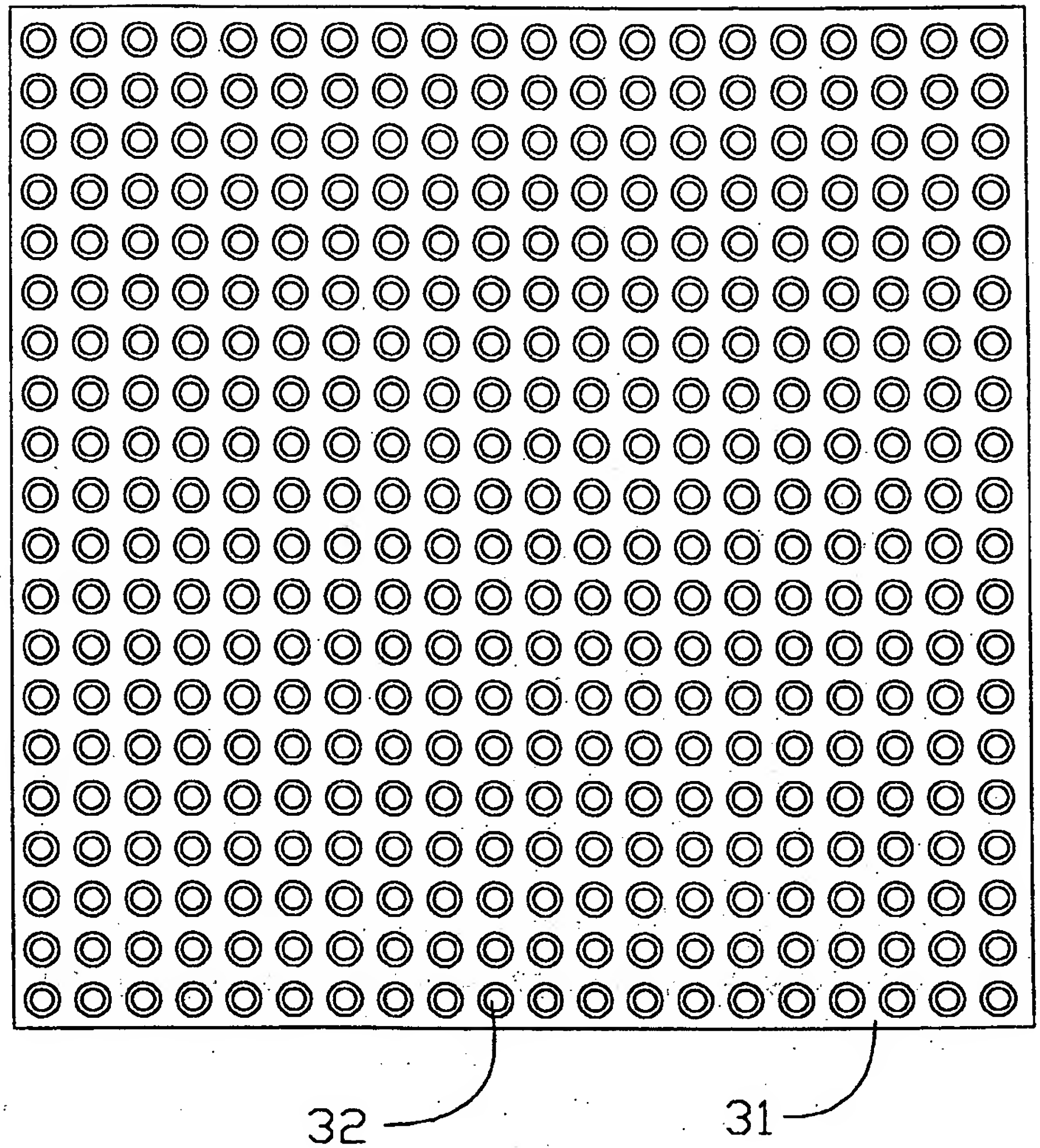


FIG. 3B

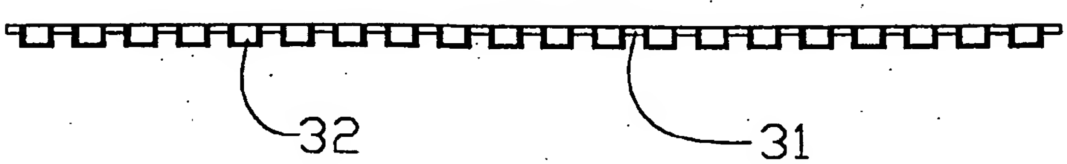


FIG. 4A

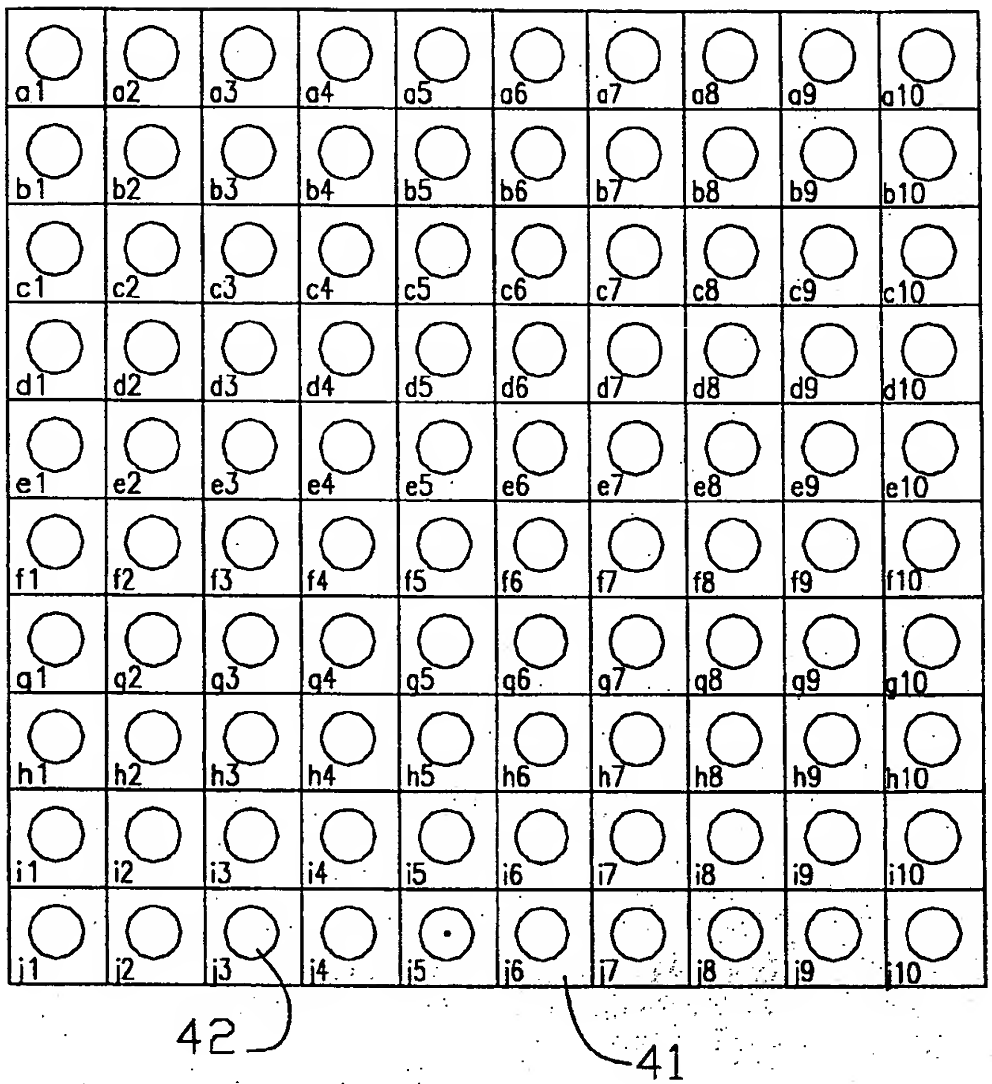

a1
a2
a3
a4
a5
a6
a7
a8
a9
a10
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
c1
c2
c3
c4
c5
c6
c7
c8
c9
c10
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
e1
e2
e3
e4
e5
e6
e7
e8
e9
e10
f1
f2
f3
f4
f5
f6
f7
f8
f9
f10
g1
g2
g3
g4
g5
g6
g7
g8
g9
g10
h1
h2
h3
h4
h5
h6
h7
h8
h9
h10
i1
i2
i3
i4
i5
i6
i7
i8
i9
i10
j1
j2
j3
j4
j5
j6
j7
j8
j9
j10
42
41

FIG. 4B

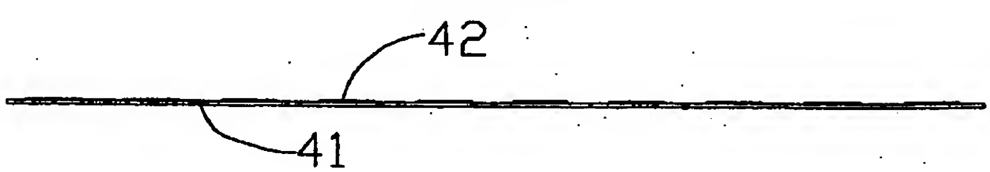

42
41

FIG. 5A

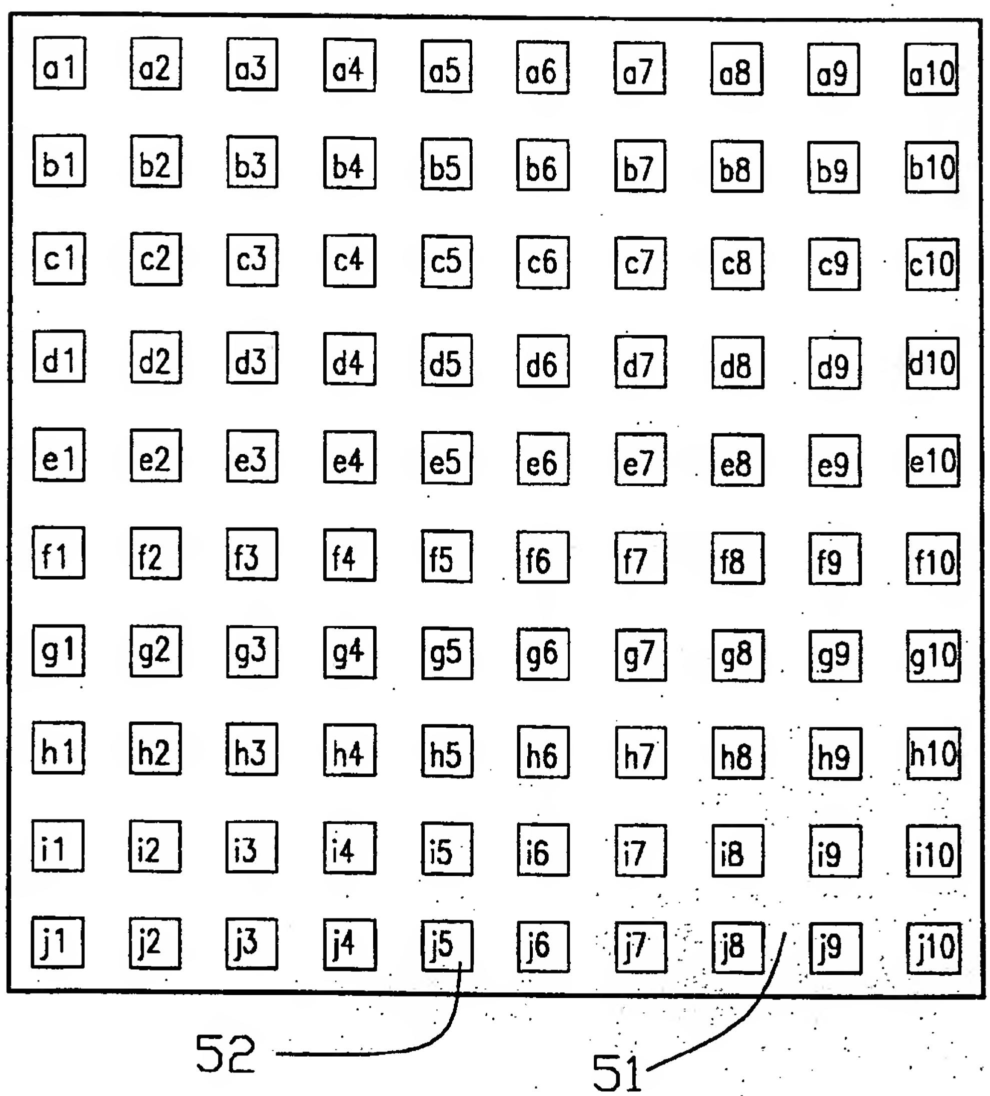
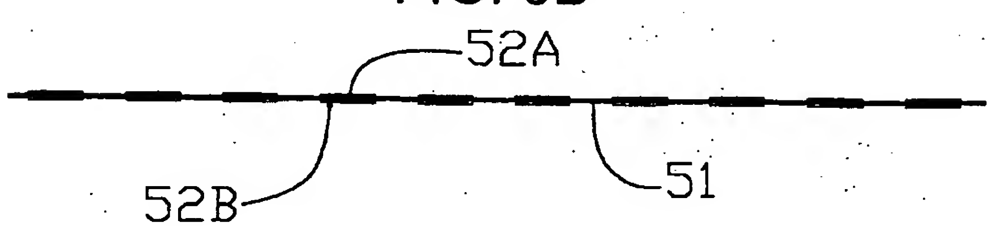

a1
a2
a3
a4
a5
a6
a7
a8
a9
a10
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
c1
c2
c3
c4
c5
c6
c7
c8
c9
c10
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
e1
e2
e3
e4
e5
e6
e7
e8
e9
e10
f1
f2
f3
f4
f5
f6
f7
f8
f9
f10
g1
g2
g3
g4
g5
g6
g7
g8
g9
g10
h1
h2
h3
h4
h5
h6
h7
h8
h9
h10
i1
i2
i3
i4
i5
i6
i7
i8
i9
i10
j1
j2
j3
j4
j5
j6
j7
j8
j9
j10
52
51

FIG. 5B


52A
52B
51

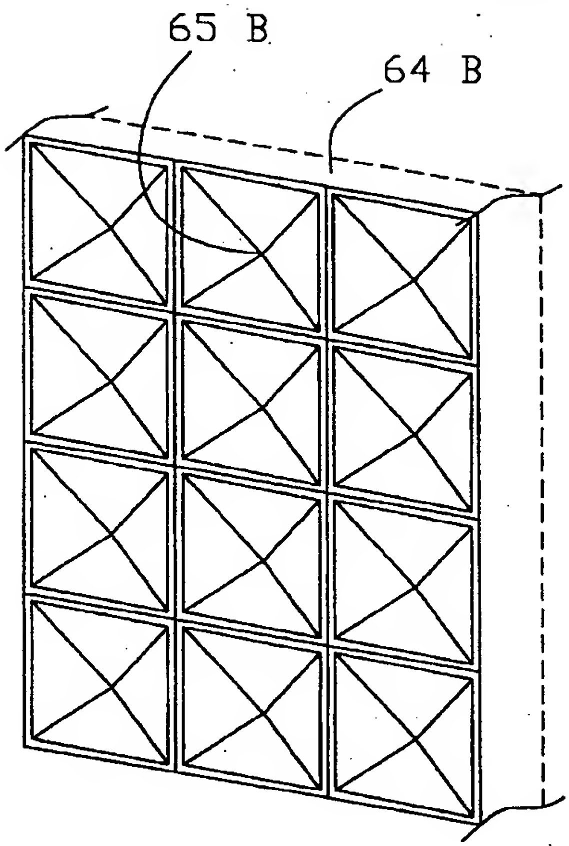


FIG. 6A

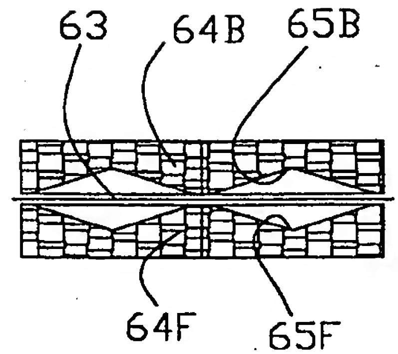


FIG. 6B

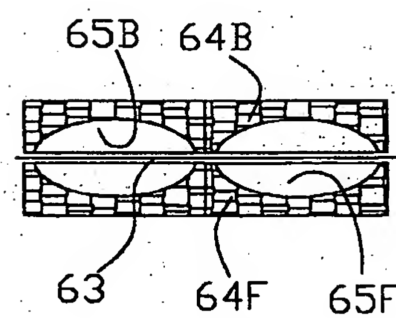


FIG. 6C

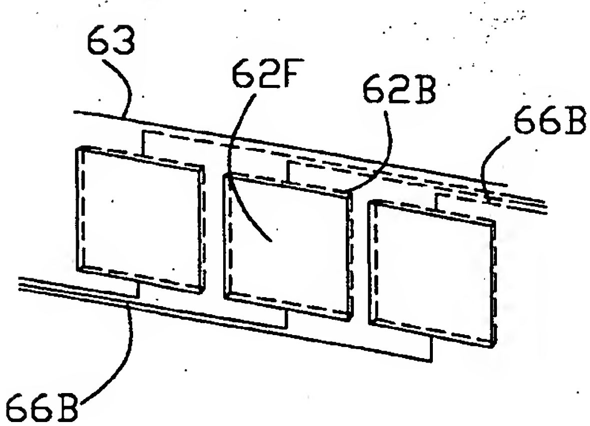


FIG. 6D

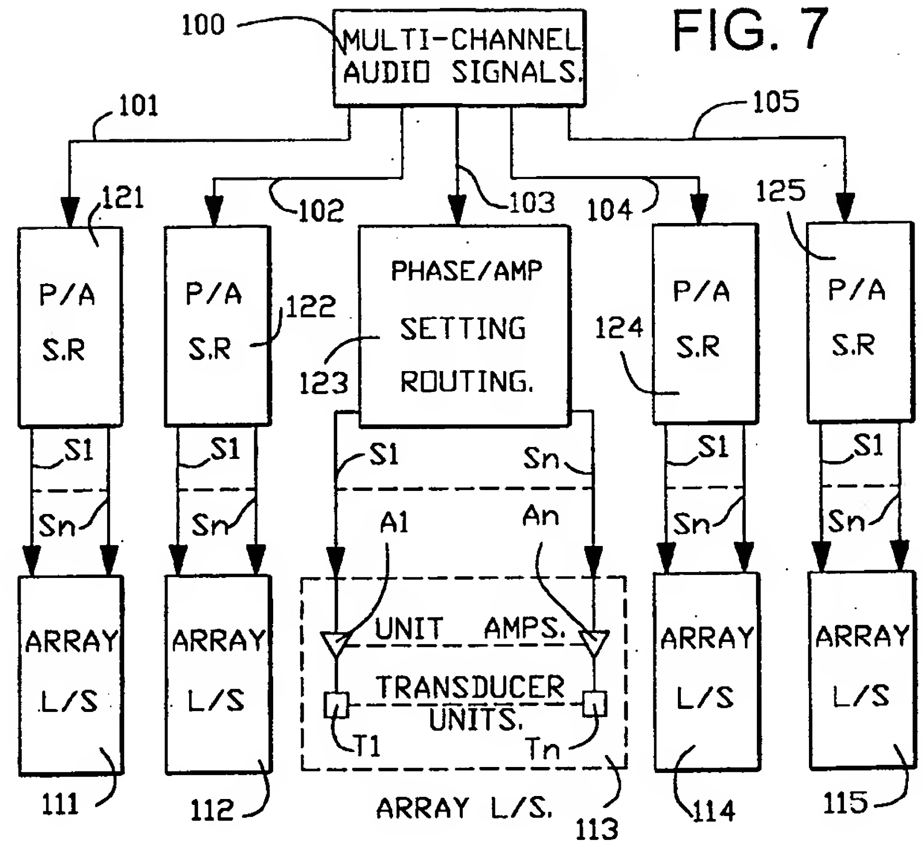

100
MULTI-CHANNEL AUDIO SIGNALS.
101
102
103
104
105
121
122
123
124
125
P/A S.R
PHASE/AMP SETTING ROUTING.
S1
Sn
A1
An
ARRAY L/S
UNIT AMPS.
TRANSDUCER UNITS.
T1
Tn
ARRAY L/S.
111
112
113
114
115

FIG. 7

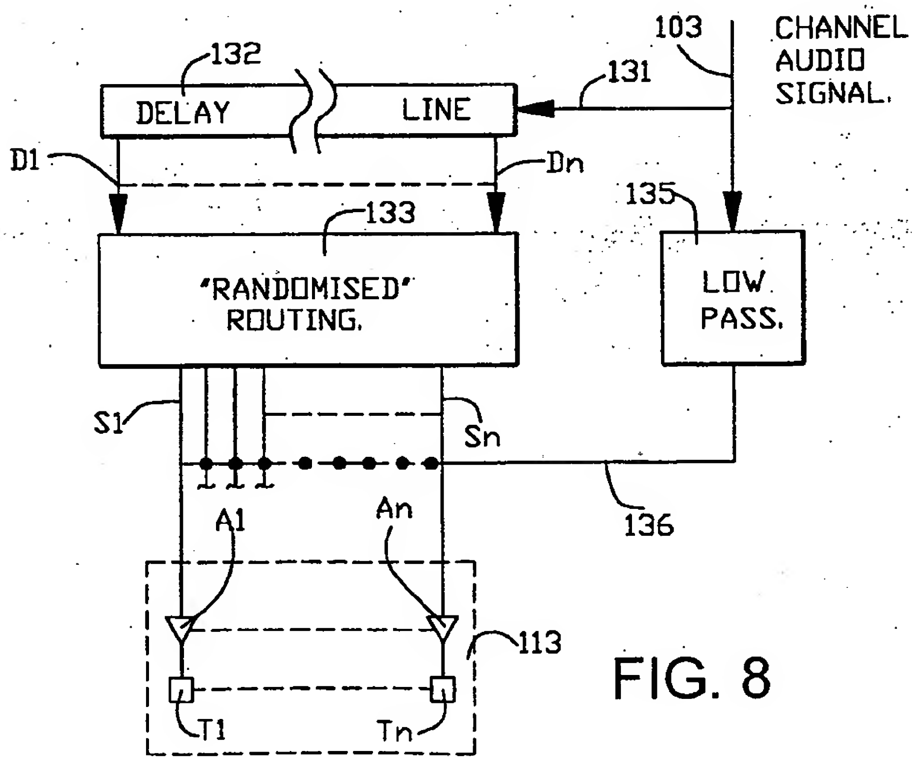

103
CHANNEL AUDIO SIGNAL.
131
132
DELAY
LINE
D1
Dn
133
'RANDOMISED' ROUTING.
135
LOW PASS.
S1
Sn
136
A1
An
113
T1
Tn

FIG. 8

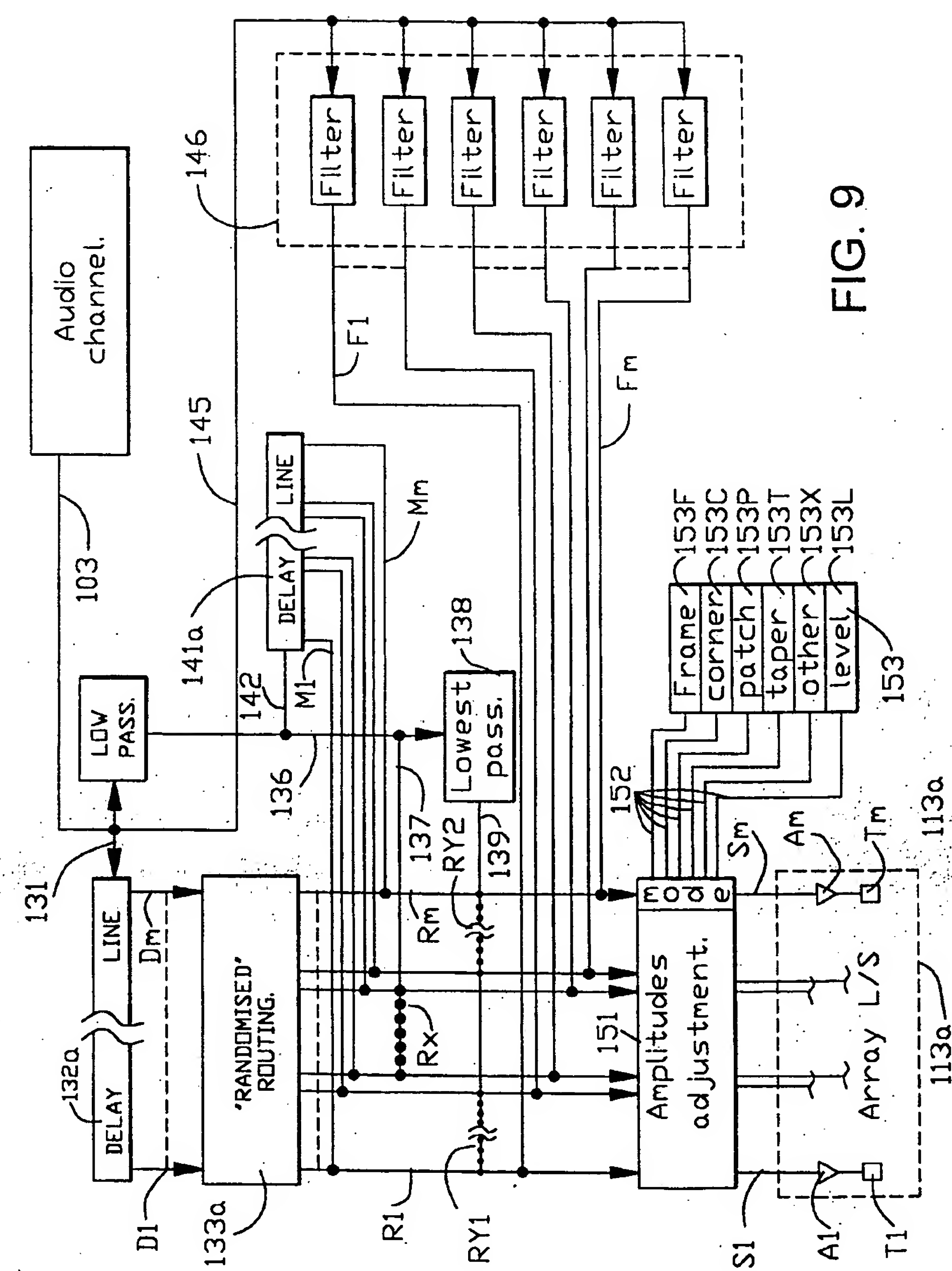

Audio channel.
146
Filter
Filter
Filter
Filter
Filter
Filter
F1
Fm
145
103
LINE
DELAY
Mm
141a
M1
142
LOW PASS.
136
Lowest pass.
138
137
RY2
139
Frame
corner
patch
taper
other
level
153F
153C
153P
153T
153X
153L
153
152
131
LINE
DELAY
Dm
132a
'RANDOMISED' ROUTING.
133a
D1
R1
RY1
Rm
Rx
151
Amplitudes adjustment.
m
o
d
e
Sm
S1
Am
A1
Tm
T1
Array L/S
113a

FIG. 9

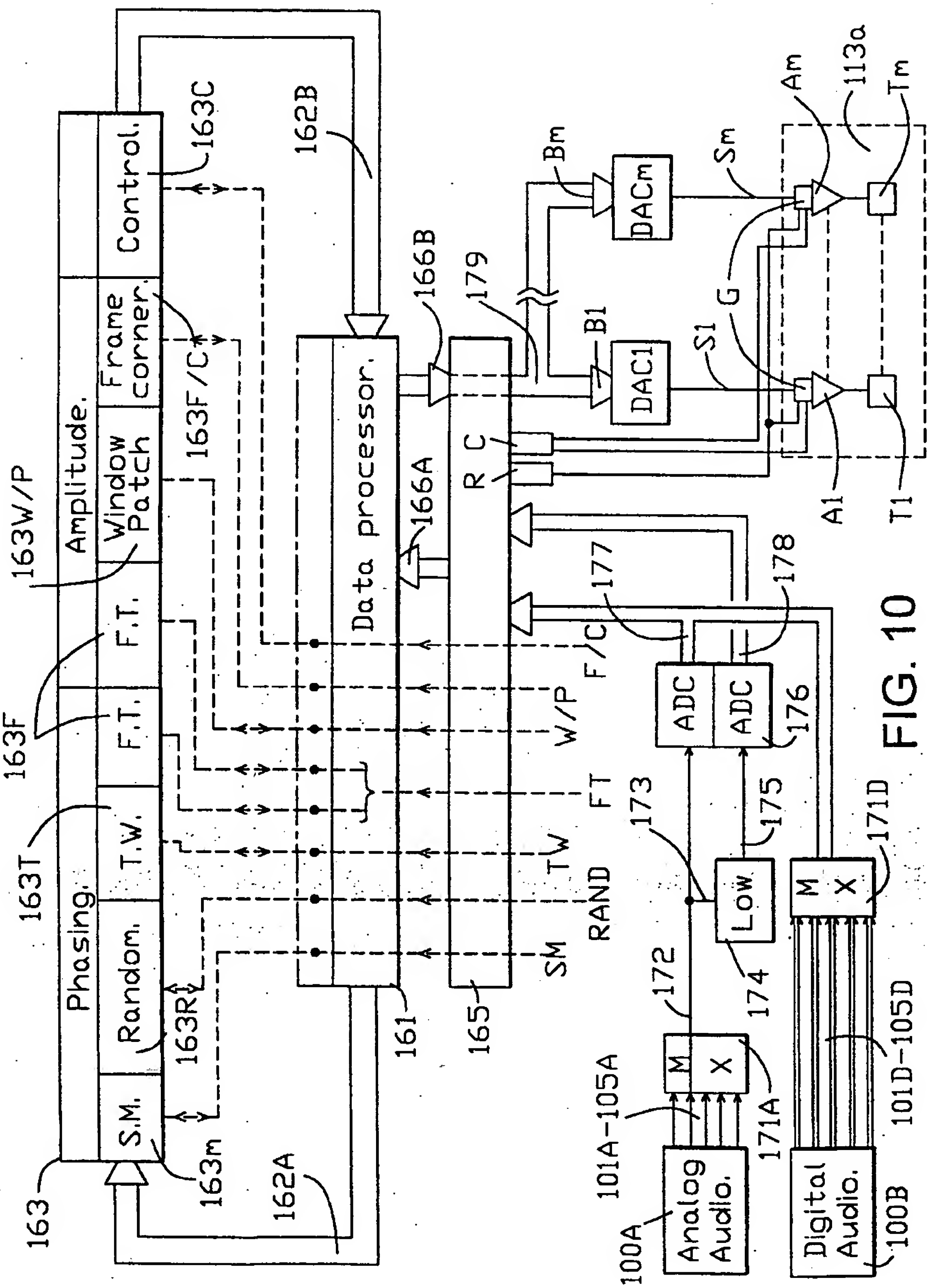

Phasing.
Amplitude.
S.M.
Random.
T.W.
F.T.
F.T.
Window Patch
Frame corner.
Control.
Data processor.
R
C
DAC1
DACm
ADC
ADC
Low
M
X
M
X
Analog Audio.
Digital Audio.
SM
RAND
TW
FT
W/P
F/C
163
163m
163R
163T
163F
163W/P
163F/C
163C
162A
162B
161
165
166A
166B
179
B1
Bm
S1
Sm
G
A1
Am
T1
Tm
113a
172
173
174
175
176
177
178
171A
171D
100A
100B
101A–105A
101D–105D

FIG. 10